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AUTHOR DiLuzio, Geneva J.; And Others
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ABSTRACT

This document accompanies the Conceptual Learning and Development Assessment Series I: Equilateral Triangle, a test constructed to chart the conceptual development of individuals. As a technical manual, it contains information on the rationale, development, standardization, and reliability of the test, as well as essential information and statistical data for evaluating the test. This report is designed to be used by individuals who have a general knowledge of test construction and measurement principles and are aware of the limitations of test interpretations. The authors of this manual have attempted to take into account and satisfy the standards set forth by the American Psychological Association regarding educational and psychological tests. The test is based upon the Conceptual Learning and Development (CLD) Model, which suggests four successive levels of concept learning: (1) concrete--recognizing an object which has been encountered previously; (2) identity--recognizing a known object when it appears in a different spatial, time, or sensory perspective; (3) classificatory--generalizing that two items are alike in some way; and (4) formal--naming and defining the concept, listing its attributes, and judging the presence of such attributes in an object. (Author/GDC)

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Technical Report No. 434

TECHNICAL MANUAL FOR THE CONCEPTUAL LEARNING AND
DEVELOPMENT ASSESSMENT SERIES I: EQUILATERAL TRIANGLE

by Geneva J. DiLuzio, Conrad G. Katzenmeyer,
and Herbert J. Klausmeier

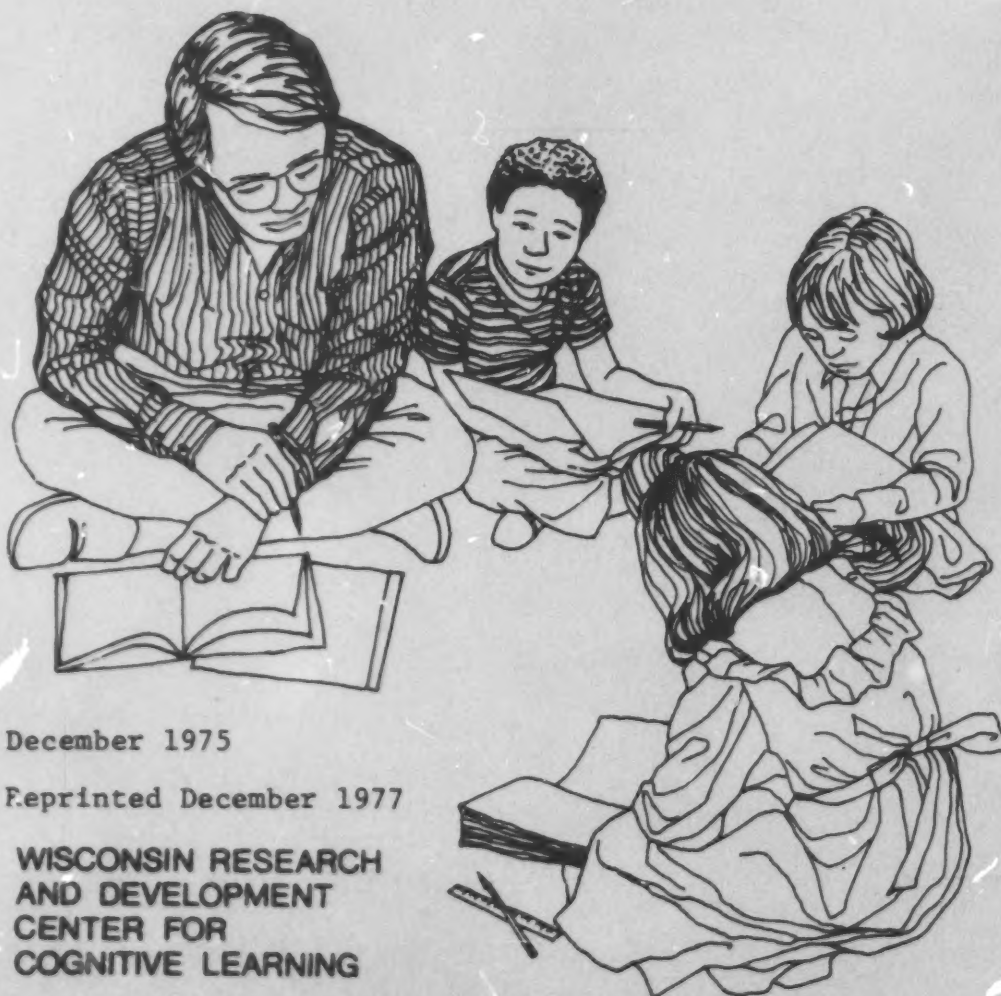
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Report from the
Technical Services Section

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

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CENTER FOR COGNITIVE LEARNING

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ABSTRACT

This technical manual is one of three related publications to be used with the Conceptual Learning and Development Assessment Series I: Equilateral Triangle, a test constructed to chart the conceptual development of individuals. As a technical manual, it contains information on the rationale, development, standardization, and reliability of the test, as well as essential information and statistical data for evaluating the test.

This report is designed to be used by individuals who have a general knowledge of test construction and measurement principles and are aware of the limitations of test interpretations. The authors of this manual have attempted to take into account and satisfy the standards set forth by the American Psychological Association regarding educational and psychological tests.

An overview of the theoretical framework on which the test is based, a copy of the preliminary edition of the test battery, and directions for administration can be found in the Working Paper, Development of Conceptual Learning and Development Assessment Series I: Equilateral Triangle (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973).

The most complete source of information regarding the theoretical framework on which the test is based is in Conceptual Learning and Development: A Cognitive View (Klausmeier, Ghatlala, & Prager, 1974).

RATIONALE OF THE TEST

OVERVIEW OF THE CONCEPTUAL LEARNING AND DEVELOPMENT MODEL (CLD): THE BASES FOR TEST DEVELOPMENT

This technical manual provides information on the rationale, development, and statistical properties of the Conceptual Learning and Development Assessment Series I: Equilateral Triangle. The test battery is based upon the model of conceptual learning and development (CLD model) proposed by Klausmeier (1971) and more fully described by Klausmeier, Ghatala, and Frayer (1974). The CLD model is the theoretical framework which provides the basis for determining children's level of attainment and use of a particular concept.

The Conceptual Learning and Development Series I: Equilateral Triangle was developed in the course of research on the CLD model for use in typical school settings. By providing the researcher with a measure of conceptual attainment, it permits the study of the relationships of level of conceptual attainment, concept usage, internal conditions of concept learning, and instructional conditions (Klausmeier, Ghatala, & Frayer, 1974). The instrument is unique in that it provides a standardized measure of the level of attainment of the concept equilateral triangle and the uses of that concept, and it can be group administered.

General Characteristics of the CLD Model

The general characteristics of the CLD model are summarized by Klausmeier, Ingison, Sipple, and Katzenmeyer (1973): It is an analytical,

descriptive model. It defines four successive levels of concept attainment and three types of concept usage. It specifies cognitive operations which are involved in learning concepts at each of the four levels. It relates internal and external conditions of learning to the specified levels.

Definition of Concepts

Klausmeier, Ghatala, and Frayer (1974) use the word concept to designate mental constructs of individuals as well as identifiable public entities which are part of the substance of various disciplines. Klausmeier, Davis, Ramsay, Fredrick, and Davies (1965) developed a definition of concept as an entity having a set of defining attributes, which is characteristic of concepts from a variety of disciplines. In addition, Klausmeier, Ghatala, and Frayer (1974) specified that most public concepts have eight attributes: learnability, usability, validity, generality, power, structure, instance numerousness, and instance perceptibility. Systematic analysis of a particular concept with regard to its various attributes is the method used to delineate the particular concept to be assessed by the battery and determine the format of the items used.

Structure of the Model

Levels of Concept Attainment. Four successive levels of concept attainment are specified by the model: concrete level, identity level, classificatory level, and formal level. Klausmeier, Ingison, Sipple, and Katzenmeyer (1973) describe the levels of attainment as follows:

Attainment of a concept at the concrete level is inferred when the individual cognizes an object that he has experienced on a prior occasion. At this level, the object is experienced in exactly the same way on the second and later occasions. Attainment of a concept at the identity level is inferred when the individual cognizes an object as the same one previously encountered when observed from a different spatio-temporal perspective or sensed in a different modality. The attainment of a concept at the classificatory level is inferred when the individual treats at least two instances of the same set of things as equivalent. At this level the individual may be unable to name the attributes that are common to the instances. Attainment of a concept at the formal level is inferred when the individual can name the concept, discriminate and name the societally accepted defining attributes and values, and accurately evaluate instances as belonging or not belonging to the set in terms of the presence or absence of the defining attributes [p. 7].

The normative pattern postulated for individuals who are attaining a concept is to move successively from each level to the next higher level given the following conditions: First, the concept is of the kind for which there are either actual instances or representations of instances observable in the environment; and second, the individual has had experience with the instances beginning in early childhood (Klausmeier, Ghatala, & Frayer, 1974). It is acknowledged that some concepts are not attained at all four of the successive levels. This can occur either because of the nature of the concepts or because the learning experiences of the individual do not permit their acquisition.

Concept Utilization and Extension. Once a concept is attained at the classificatory or formal levels it may be used in four ways. The first use is an example of horizontal transfer, in which the individual can use the attained concept in recognizing newly encountered examples and nonexamples. The three other uses, cognizing supraordinate-subordinate relations, cognizing various other relations among concepts, and generalizing to problem-solving situations, are examples of vertical

transfer, in which individuals extend their knowledge about an attained concept by using it. It is not implied that attainment of the concepts at the classificatory level or formal level will be followed by mastery of all the uses.

In cognizing supraordinate-subordinate relations, individuals can, after verbal instruction, place instances of hierarchically related concepts into proper groups and can justify their decisions based on the defining attributes of the group. At higher levels individuals are able to understand relationships described as the "whole is the sum of the parts" and "some but not all (Kofsky, 1966)." Understanding supraordinate-subordinate relationships increases the validity and usability of the individual's concepts (Klausmeier, Ghatala, & Frayer, 1974).

There are other statements of relations between or among concepts which involve causality, correlation, probability, or other valid relations. Being able to understand and use a valid relationship depends on knowledge of the concepts that are to be related. These types of relationships are different from relations among supraordinate and subordinate concepts (Klausmeier, Ghatala, & Frayer, 1974).

Problem solving is inferred in any situation where information about a concept or concepts is called into play and generalized to arrive at a solution to a particular problem. One example of concepts being used in problem solving is the application of familiar principles to new situations.

Other Characteristics of the Model

Information concerning the cognitive operations employed at each level of conceptual attainment and the internal and external conditions of learning necessary to concept attainment is presented in Conceptual Learning and Development: A Cognitive View (Klausmeier, Ghatala, & Frayer, 1974).

DESCRIPTION OF THE CONCEPTUAL LEARNING AND DEVELOPMENT ASSESSMENT SERIES I: EQUILATERAL TRIANGLE

Scope of the Test Battery

There are six subtests used to assess the level of conceptual attainment: concrete level, identity level, classificatory level, evaluating and defining, naming, and discriminating attributes. The last three of these subtests are used to assess attainment of the formal level. Three additional subtests are used to assess concept usage: supraordinate-subordinate relations, principles, and problem solving.

This battery may be used with children of ages 4-18. It was standardized on children at four grade levels: 1, 4, 7, and 10. The span of age represented in the standardization sample provides sufficient information to examine the usability of each subtest for children of various ages. Two forms of the test were developed, primary and intermediate. Items used in the primary form are a subset of those used in the intermediate form. In addition, a simplified set of directions is used with the primary form.

In the process of test development, certain subtests were found to be too difficult or too easy for children in some grades. Table 1 presents the set of subtests found to be most appropriate for administration at each of the four grade levels included in the standardization sample, as well as the number of items per subtest and average amount of time needed to administer each subtest for each form.

Concrete Level Subtest

This eight-item subtest is designed to assess whether a child has attained the concept equilateral triangle at the concrete level. A drawing of an equilateral triangle is presented to the child. After he has looked at the drawing for a few seconds, the child is asked to turn to the next page of the answer booklet and find the drawing that looks exactly the same among four, seven, or ten polygons. The correct choice has the same spatial orientation as on the preceding page. All instructions for this subtest are given orally and no written instructions appear.

The polygons used vary systematically with respect to shape, color, and size. By varying the number of polygons serving as alternatives and the number of attributes on which the incorrect alternatives differ from the correct choice, items of varying difficulties are obtained. Item 1 employs three incorrect alternatives, each differing from the correct choice with respect to all three attributes. Item 2 employs six distractors, each differing from the correct choice on three attributes. Items 3 and 4 use three and six distractors respectively, each differing on only two attributes from the correct choice. Items 5 and 6 use three and six distractors respectively, each differing

TABLE 1

APPROPRIATENESS, AVERAGE ADMINISTRATION TIME, AND ITEM CONTENT OF THE
 VARIOUS SUBTESTS OF THE CONCEPTUAL LEARNING AND DEVELOPMENT ASSESSMENT
 SERIES I: EQUILATERAL TRIANGLE FOR CHILDREN IN DIFFERENT GRADE GROUPS
 IN THE STANDARDIZATION SAMPLE

Subtest	Number of items				Average administration time in minutes			
	Primary form	Intermediate form			Primary form	Intermediate form		
	Grade 1	Grade 4	Grade 7	Grade 10	Grade 1	Grade 4	Grade 7	Grade 10
Concrete Level	8	NA	NA	NA	} 5	} NA	} NA	} NA
Identity Level	8	NA	NA	NA				
Classificatory Level	3	3	3	3	3-5	3	3	3
Evaluating and Defining	5	6	6	6	6	6	6	6
Naming	6	7	7	7	8	8	8	8
Discriminating Attributes	5	5	5	5	3	2	2	2
Supraordinate-Subordinate Relationships	NA	8	8	8	NA	5	5	5
Principles	NA	11	11	11	NA	8	8	8
Problem Solving	NA	6	6	6	NA	7	7	7
Total Battery	35	46	46	46	27	39	39	39

NA = Not appropriate for these grade groups.

from the correct choice with respect to only one attribute. Items 7 and 8 each employ nine distractors, each of which differs from the correct choice with respect to either one or two attributes. The placement of the correct choice among the distractors is varied randomly across the eight items.

Five shapes, three colors, and three sizes are employed. The shapes used are equilateral triangle, right triangle, isosceles triangle, square, and rectangle. The colors employed are blue, red, and yellow. Each figure may appear in three different sizes, designated small, medium, and large. The sides of the small figures are on the order of .5 to .9 centimeters in length, the sides of the medium figures are on the order of .9 to 1.8 centimeters in length, and the sides of the large figures are approximately 1.8 to 3.6 centimeters. Table 2 presents the polygon attributes used in each item in the concrete level subtest. The three-letter descriptors indicate the shape, color, and size of each polygon, in that order, using these abbreviations:

<u>Shapes</u>		<u>Colors</u>		<u>Sizes</u>	
E	Equilateral Triangle	B	Blue	S	Small
R	Right Triangle	R	Red	M	Medium
I	Isosceles Triangle	Y	Yellow	L	Large
S	Square				
Q	Rectangle				

Figures of the same description are used in the identity level, classificatory level, and supraordinate-subordinate subtests, and the same sets of abbreviations will be used in referring to them.

TABLE 2
ATTRIBUTES OF POLYGONS EMPLOYED
IN THE CONCRETE LEVEL SUBTEST

Item	Correct Choice	Other polygons serving as alternatives
1	FYM	SBL, RRS, QRL
2	ERS	RBM, SYL, QBL, RYM, SBS, QYL
3	ERL	EBM, SBL, QRS
4	EBM	QBS, RRM, EYL, SIM, QBL, ERS
5	EYS	SYS, EBS, EYL
6	EBL	EYL, RBL, SBL, EBM, ERL, EBS
7	ERM	RRL, ERS, EBM, RRM, EYM, RRS, RBM, ERL, RYM
8	EBS	EYL, RBL, IYS, ERS, RBS, IBM, EBM, RBM, IRS

Identity Level Subtest

This eight-item subtest is designed to assess whether a child has attained the concept equilateral triangle at the identity level. In this subtest, the task and stimulus materials are like those employed at the concrete level. However, the correct choice on the second page of each item is rotated so that it has a different spatial orientation than on the preceding page. The distractors presented with the correct choice also appear in various orientations so that the correct choice is not conspicuous due to its irregular orientation. All instructions are given orally and no written instructions appear.

As in the concrete level subtest, the polygons used vary systematically with respect to shape, color, and size. The eight items are of successively increasing difficulty due to varying numbers of distractors

and varying degrees of similarity between the distractors and the correct choices. Both the pattern of the distractors and the figures used are identical to those in the concrete level subtest described above. The placement of the correct choice among the distractors is varied randomly across the eight items. The attributes of the polygons used in each item of the identity level subtest are shown in Table 3 with the three-letter abbreviations given above. The table also shows the approximate rotation of each figure in degrees counterclockwise from an orientation with the base horizontal. The longer side of the rectangle and the longer of the two sides of the right triangle excluding the hypotenuse are taken to be their bases. The target figure presented on the first page of each item is always an equilateral triangle with the base horizontal.

Classificatory Level Subtest

This three-item subtest is designed to assess whether a child has attained the concept equilateral triangle at the classificatory level. The child is asked to mark all the drawings of polygons which have the same shape as a drawing of an equilateral triangle which appears on the left side of the same page. The label "equilateral triangle" is not used. Item 1 shows five polygons including two equilateral triangles; item 2, twelve polygons including three equilateral triangles; and item 3, twenty-four polygons including six equilateral triangles. Each polygon differs from the others with respect to size, shape, and/or color. Equilateral triangles are randomly interspersed with other polygons. Instructions are read aloud, but written instructions also appear in the test booklet for each item.

TABLE 3

ATTRIBUTES OF POLYGONS EMPLOYED IN THE IDENTITY LEVEL SUBTEST,
AND THEIR APPROXIMATE DEGREES OF ROTATION

<u>Item</u>	<u>Correct Choice*</u>	<u>Other Polygons Serving as Alternatives</u>
1	EYM 60°	SBL 30°, RRS 90°, QRL 90°
2	ERS 90°	RBM 45°, QBL 130°, RYM 210°, SBS 15°, SYL 60°, QYL 90°
3	ERL 90°	EBM 60°, QRS 90°, SBL 45°
4	EBM 40°	QBS 135°, RRM 90°, EYL 80°, ERS 50°, SRM 80°, QBL 90°
5	EYS 65°	SYS 45°, EYL 100°, EBS 30°
6	EBL 25°	EYL 60°, ERL 30°, RBL 340°, SBL 50°, EBM 60°, FES 90°
7	ERM 55°	RRL 210°, ERS 50°, RRM 290°, RBM 90°, EYM 85°, RRS 335°, EBM 85°, ERL 45°, RYM 350°
8	EBS 95°	EYL 80°, RBL 175°, IYS 330°, ERS 60°, RBS 60°, IBM 180°, EBM 90°, RBM 90°, IRS 150°

* On the first page of each item, the correct choice is shown in a position corresponding to 0° rotation. The rotation given above for each correct choice is for its representation among the other alternatives on the second page of the item.

Equilateral triangles presented on the left for each item are 4.4 centimeters on a side. The specifications of the polygons presented as alternatives on the right side of the page are identical to those of the identity level subtest, except that no isosceles triangles appear in the classificatory level subtest. Table 4 presents the attributes of the polygons employed in each item, using the same three-letter abbreviations as above. All figures are presented with the base horizontal (no rotation).

TABLE 4

ATTRIBUTES OF POLYGONS EMPLOYED IN THE
CLASSIFICATORY LEVEL SUBTEST

Item	Equilateral Triangles	Other Polygons
1	ERS, EYM	SBL, RRS, QRL
2	ERS, EYL, EBM	QYL, RBL, RBS, SBM, QBM, SRS, QRS, RYM, SRI
3	ERM, EYM, EBL, EYS, EBS, ERL	QRL, SYS, SBL, QBL, RYS, RBM, SBS, RRM, QRM, RRS, SRM, RYL, QBS, RBL, QYS, SYL, QYM, SYM

Formal Level Subtests

To determine if a concept has been attained at the formal level, three subtests are required: evaluating and defining, naming, and discriminating attributes.

Evaluating and Defining Subtest. This six-item multiple-choice subscale is designed to assess a child's ability to define the concept equilateral triangle and to evaluate instances as belonging or not belonging to the

set "equilateral triangle" based on the presence or absence of the defining attributes. The first five items present a drawing of an equilateral triangle on the left-hand side of the page, labeled "X". On the right-hand side of the page are three other figure drawings. The child is asked in what way "X" is different from all the other drawings. Five alternatives are presented for each item. The first four are statements of the form "X is a _____ figure" or "X has _____." The fifth alternative for each item is "I don't know." The correct alternative is always one of the five defining attributes presented in Table 5. The sixth item in this subtest determines whether a child can recognize a definition of the concept equilateral triangle which is acceptable to content experts. The child is asked to choose the correct definition of the concept from among five alternatives, including "I don't know." Instructions are read aloud. The test question and alternatives appear in the test booklet and are also read aloud.

TABLE 5

DEFINING ATTRIBUTES BEING TESTED BY EACH OF THE FIRST
FIVE ITEMS OF THE EVALUATING AND DEFINING SUBTEST

Item	Defining Attribute
1	plane figure
2	simple figure
3	closed figure
4	having three equal sides
5	having three equal angles

Naming Subtest. This seven-item multiple-choice subtest is designed to assess a child's ability to label the societally-accepted attributes of the concept equilateral triangle. Two types of items are used in this subtest. Three items present a figure and ask the child to choose the answer which best describes or labels a particular attribute of the figure. The remaining four items each present two groups of figures and the child must choose the label which best fits all the drawings in the first group of figures but does not fit all the drawings in the second. All of the items have either four or five alternative choices, including "I don't know." Instructions are read aloud. The test questions and alternatives appear in the test booklet and are also read aloud. The names of the attributes tested by each item appear in Table 6.

Discriminating Attributes Subtest. This five-item subtest is designed to assess a child's ability to discriminate the societally-accepted attributes of the concept equilateral triangle. In each item, four figures are presented and the child is asked to indicate the drawing which is different from the other three or to indicate the figure which has some particular property. In each case the correct alternative is the only drawing which possesses some defining attribute of the concept equilateral triangle. The position of the correct alternative is varied randomly across the five items. The defining attributes assessed by each item are presented in Table 7. Instructions are read aloud and also appear in the test booklet with each item.

Supraordinate-Subordinate Relations Subtest

This eight-item multiple-choice subtest is designed to assess a child's ability to relate the concept equilateral triangle to supra-ordinate, subordinate, and coordinate concepts. The child's under-

TABLE 6

NAMES OF ATTRIBUTES TESTED
BY EACH ITEM OF THE NAMING SUBTEST

<u>Item</u>	<u>Attribute Label</u>
1	equal
2	triangle
3	angle
4	closed figure
5	side
6	equilateral triangle
7	simple figure

TABLE 7

DEFINING ATTRIBUTES BEING TESTED BY EACH ITEM
OF THE DISCRIMINATING ATTRIBUTES SUBTEST

<u>Item</u>	<u>Attribute Distinguishing Correct Choice</u>	<u>Attribute Possessed by Remaining Alternatives</u>
1	closed figure	open figure
2	simple figure	complex figure
3	plane figure	solid figure
4	equal sides	unequal sides
5	equal angles	unequal angles

standing of four types of relations is assessed, with two items for each type. In each item six or eight figures are presented and a question is asked concerning the relationship of various subsets. The description of the figure attributes employed is the same as for the identity level subtest, except that no isosceles triangles are used. Statements of the four relations tested are given in Table 8, as are lists of all the figures presented for each item and lists of those figures which are examples of the supraordinate, subordinate, and/or coordinate classes to be related for each item. Examples of the polygon classes referred to in the items are "three-sided figures," "equilateral triangles," "right triangles," "red figures," etc. The child must select the correct answer to the test question from among four alternatives, including "I don't know." Instructions are read aloud. The test questions and alternatives appear in the test booklet and are also read aloud.

Principles Subtest

This eleven-item multiple-choice subtest is designed to assess whether a child understands various valid relationships among the properties of the concept equilateral triangle. These relationships are stated as five principles, each of which is tested both with and without illustration. In both cases the child is presented with an incomplete statement of a valid relationship between various properties of the concept. The child must complete the statement by selecting the correct alternative from among four or five phrases, including "I don't know." Instructions are read aloud. The test questions and alternatives appear in the test booklet and are also read aloud. The

TABLE 8

RELATIONS TESTED AND CLASSES OF FIGURES EMPLOYED
IN THE SUPRAORDINATE-SUBORDINATE RELATIONS SUBTEST

Item	Type of relation- ship*	Figures presented	Type of first class(es) involved in statement of relation	Figures in first class(es)	Type of second class involved in statement of relation	Figures in second class
1	I	RBM, EBL, RYL, ERM, EYS, RRS	Supraordinate	RBM, EBL, RYL, ERM, EYS, RRS	Subordinate	EBL, ERM, EYS
2	II	RBM, EBL, RYL, ERM, EYS, RRS	Subordinate	EBL, ERM, EYS	Supraordinate	RBM, EBL, RYL, ERM, EYS, RRS
3	III	RBM, EBL, RYL, ERM, EYS, RRS	Subordinate Subordinate	EBL, ERM, EYS RBM, RYL, RRS	Supraordinate	RBM, EBL, RYL, ERM, EYS, RRS
4	IV	RBM, EBL, RYL, ERM, EYS, RRS	Coordinate	ERM, RRS	Coordinate	EBL, ERM, EYS
5	IV	RYS, EBL, ERS, RRL, RBS, EYL	Coordinate	RYS, ERS, RBS	Coordinate	EBL, ERS, EYL
6	II	QYM, SBL, ERL, EBM, SRS, QBL, RYS, RRM	Subordinate	ERL, EBM, RYS, RRM	Supraordinate	QYM, SBL, ERL, EBM, SRS, QBL, RYS, RRM
7	I	QYM, SBL, ERL, EBM, SRS, QBL, RYS, RRM	Supraordinate	QYM, SBL, ERL, EBM, SRS, QBL, RYS, RRM	Subordinate	ERL, EBM, RYS, RRM
8	III	QYM, SBL, ERL, EBM, SRS, QBL, RYS, RRM	Subordinate Subordinate	ERL, EBM, RYS, RRM, QYM, SBL, SRS, QBL	Supraordinate	QYM, SBL, ERL, EBM, SRS, QBL, RYS, RRM

*The four relationships are as follows:

- I. Some but not all members of a supraordinate class belong to a given subclass.
- II. All members of a subclass are also members of a higher class.
- III. The sum of the members of the subclasses equals the sum of the members of the supraordinate class.
- IV. The members of one coordinate class are not members of another coordinate class.

principle tested in each item is listed in Table 9a, which also indicates whether or not an illustration is used with each item.

Problem-Solving Subtest

This six-item multiple-choice subtest is designed to assess a child's ability to apply knowledge of the concept equilateral triangle in a particular problem-solving situation. For each item a drawing involving an equilateral triangle is presented and the child is asked to solve a problem requiring the application of one of the five principles mentioned above. The child must select the correct alternative from five choices, including "I don't know." The principle required for each item is presented in Table 9b. Instructions are read aloud. Test questions and alternatives appear in the test booklet and are also read aloud.

Additional Information for the Concept "Equilateral Triangle"

Information regarding the concept analysis of equilateral triangle is available in the document by Klausmeier, Katzenmeyer, and Sipple (1973). This information includes definition of the concept; defining relevant and irrelevant attributes; examples and nonexamples of the concept used to assess the concrete, identity, classificatory, and/or formal levels and in supraordinate-subordinate relations, principles, and/or problem-solving; taxonomy of concepts related to equilateral triangle; and principles related to the concept. The source also gives a description of the content of each item in terms of the number and nature of the nonexamples used in the concrete and identity subtests, descriptions of the relationships being assessed in the supraordinate-subordinate relations subtest, the attributes tested in the discriminating

TABLE 9

PRINCIPLES ASSESSED AND USE OF ILLUSTRATIONS
IN THE PRINCIPLES AND PROBLEM-SOLVING SUBTESTS

a. <u>Principles Subtest</u>		
Item	Principle*	Format
1	III	with illustration
2	II	with illustration
3	IV	with illustration
4	IV	with illustration
5	I	with illustration
6	V	with illustration
7	III	without illustration
8	II	without illustration
9	V	without illustration
10	IV	without illustration
11	I	without illustration
b. <u>Problem Solving Subtest</u>		
Item	Principle*	Format
1	II	with illustration
2	V	with illustration
3	IV	with illustration
4	IV	with illustration
5	III	with illustration
6	I	with illustration

*The five principles are as follows:

- I. All equilateral triangles are similar (in shape).
- II. If the three angles of a triangle are equal in the number of degrees, the sides of the triangle are of equal lengths.
- III. If the three sides of a triangle are of equal length, the angles of the triangle are equal in the number of degrees.
- IV. A line that bisects any angle of an equilateral triangle forms two equal angles (lines) when it intersects the opposite side.
- V. The perimeter of an equilateral triangle is three times the length of any side.

attributes subtest, principles being tested in the principles and problem-solving subtests, and labels tested in the naming subtest.

DEVELOPMENT OF THE CONCEPTUAL LEARNING AND DEVELOPMENT ASSESSMENT SERIES I: EQUILATERAL TRIANGLE

Guidelines Used in Test Development

At the beginning of the test development activity the following guidelines were established for test construction and selection of a concept to be assessed. Test materials and instructions were to be appropriate for use with children from preschool age through high school and the test was to be group administered. It was necessary to choose a concept which could be presented in a paper-and-pencil format, which lent itself to definition in terms of defining attributes, and which was found in typical school curricula. The concept to be assessed had to be part of a taxonomy of related concepts, so that cognizing supraordinate and subordinate relationships could be tested; it also had to be usable in cognizing principles and in problem solving.

The concept equilateral triangle was chosen to satisfy these guidelines for the curriculum area of mathematics. Three other batteries were constructed to assess concepts in other curriculum areas.

A second set of guidelines was used in developing the directions for test administration and item formats. The purpose of these guidelines was to ensure that valid responses could be obtained from children of all ages. First, "practice" questions would be offered.

Second, specific repetitions of instructions or questions would be prescribed for use with younger children to ensure that they fully grasped the nature of the task. Third, all items would be read aloud by the test administrator since reading ability was not the specific measurement objective. Fourth, attractive item formats would be used to engage the interest of the children. Fifth, all stimulus and response materials, such as in the classificatory items, would be arranged in a left-to-right flow. Sixth, items and pages would be designed so that children could easily keep their places.

Writing Items

Items were written according to specifications provided by the concept analyses and the guidelines reviewed earlier. Item writing was done by scholars at the Wisconsin Research and Development Center for Cognitive Learning who were knowledgeable in the area of conceptual learning and development and use of the CLD model. Guidance for item writing was provided by a measurement specialist who reviewed and edited all test items.

Review of Test Battery Content by Specialists

The test battery was reviewed for mathematical accuracy by a content specialist in the area of mathematics. Any inaccuracies in items were corrected at that time.

Tryout of Items

After the reviewing and editing were completed, the items and test directions were given an empirical tryout in fall of 1972 using a small group of students in each of grades K, 3, 6, and 9. Results of the tryout provided information regarding the clarity of instructions and illustrations, comprehensibility of test questions and alternatives, and amount of time needed to administer the battery. Finally, the results were examined to see if the younger children were biased toward selecting particular answer positions in the test booklet. Children selected for participation in the tryout included an equal number of boys and girls in the categories of high, medium, and low scholastic achievers in order to ensure that information concerning clarity of directions and estimates of time needed to administer the test would be generalizable to the entire school populations. As a result of the tryout, items and test instructions were further revised and became the preliminary edition of the battery.

Preliminary Edition

The preliminary edition of the battery was used in winter of 1972 at two testing sites. Both sites were small Midwestern cities and all children tested were enrolled in public schools. The preliminary edition was administered to kindergartners, third, sixth, and ninth graders at both sites. Approximately 100 children were tested at each of the grade levels at the first site; at the second site approximately 60 kindergartners, 85 third graders, 90 sixth graders, and 85 ninth graders were tested. Test administrations at both sites

were done by the same trained personnel from the Wisconsin Research and Development Center for Cognitive Learning.

The preliminary edition provided several types of information: analysis of the difficulty and discrimination indices of each item, reliability of the test, and the usability of the test with children in different grade groups.

Separate analyses were performed on the information from each of the two testing sites. Results from both sites indicated that only a very few item revisions were required to produce final test forms which would be suitable for the intended population of normal school children. It was concluded that the tests and the directions were appropriate for group administration to children of various ability levels in a wide range of grade groups.

Development of Final Edition

Writing of Additional Items. At the completion of the analyses and review of the preliminary edition, a final edition of the battery was developed. Since only minor revisions were made to the preliminary edition, the most significant difference between the two editions was the addition of several new items. Specifically, five evaluating items were added, as well as two new discriminating attributes items. The same procedure for review and editing was followed for these items as was used in the development of the preliminary versions. No new directions for administration of the evaluating items were required since these items were incorporated into an existing test booklet and were formatted similarly to the items just preceding them. A definition item was also added to the battery.

Production of Final Test Materials. A number of factors were considered in constructing the battery booklets to increase standardization of administration. The points incorporated in the standardized battery ensure that the children perform to their best advantage. First, instructions specific to each item are read aloud and also appear in the test booklet, reducing the influence of reading ability on test scores. Second, the STOP instruction is prominently placed at the end of each item or bottom of each page as in the concrete and identity subtests. Third, readability of the print is enhanced by use of a primary typewriter and sufficient spacing between items to eliminate confusion. Fourth, the brightly colored polygons used in the test items make the booklets attractive, which serves to stimulate interest in taking the test.

The test is produced in four booklets. The pages of the two test booklets that contain the colored polygons are encased in plastic to make them reusable. Children mark their choice using a grease pencil. Test booklets must be cleaned after a child's responses have been recorded. The other two test booklets are produced in a typical paper-and-pencil format and children mark their answers directly on them.

Writing of Test Administration Manuals. The general instructions were prepared to increase the uniformity with which the test is administered. Procedures and materials to be used in the testing program are clearly outlined in Development of Conceptual Learning and Development Series I: Equilateral Triangle (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973).

Instructions for administering specific subtests were developed on the basis of information gathered from the tryout of items on a small sample of children, criticisms and suggestions of test specialists, and suggestions of personnel who administered the test. The main

criteria for these directions were clarity and usability. The test administration manual, found in the document Development of Conceptual Learning and Development Assessment Series I: Equilateral Triangle (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973), was provided for the preliminary edition, but it serves equally well for the final edition which includes the new evaluating items. One advantage of the manual is the inclusion of the text printed in the children's test booklets. This feature reduces the number of booklets that have to be manipulated during test administration.

Computerized Analyses of Test Results. All information collected during the process of test development was prepared for electronic data processing. Personnel from the Wisconsin Research and Development Center for Cognitive Learning first transferred each child's responses from a test booklet to an answer sheet and then keypunched these responses on computer cards. A computer program was used to score the data and generate records which were used in subsequent analyses.

Summary

This section of the technical manual has emphasized the steps taken at each point in the development of the test battery. From the formulation of the theoretical framework and rationale, to the item writing and editing, through the tryout and preliminary edition, steps were taken to develop a final version of the instrument that would measure the level of conceptual attainment and usage of the concept equilateral triangle.

II

STANDARDIZATION

The standardization of the Conceptual Learning and Development Assessment Series I: Equilateral Triangle was designed to provide information about the test and its appropriateness for use with populations of normal children across a span of several grade groups.

DESCRIPTION OF THE STANDARDIZATION SAMPLE

The standardization testing was conducted in winter of 1972 in Beloit, Wisconsin. Beloit's child and adult populations are representative of many small manufacturing-industrial communities in the Midwest. In 1972 the Beloit population was 35,729, including a black population of 2606 (7 percent of the total population), and 17,255 persons (48 percent of the total) under 25 years of age. The economic level of the community is somewhat higher than the average for Midwest industrial communities: The 1970 average income per household was \$9460.00 and the median home value was \$18,000.00 (Hooper & Klausmeier, 1973).

In the Beloit public school system there are 14 elementary schools, 3 junior high schools, and 1 senior high school. Total enrollment in these schools at the time of the standardization was approximately 10,000 students. Schools in which children were tested were selected in accord with the representative socioeconomic, ethnic, and general demographic classifications found in the city of Beloit (Hooper & Klausmeier, 1973).

Stratification variables used in selecting the population within each school were grade group and sex. Children from grades 1, 4, 7, and 10 were tested with an approximately equal number of boys and girls from each grade. The size, mean age, and range of age of the standardization sample for each grade group are presented in Table 10.

In the first year of the study, intact classrooms were randomly selected from among the schools chosen to represent the range of demographic characteristics discussed earlier. These children also served as the standardization sample for each of the other three batteries developed in the Conceptual Learning and Development Assessment Series.

These children are also the target population of a four-year longitudinal study to chart the course of conceptual development in children 4 to 18 years of age. In the first year of the longitudinal study, these children were tested using the preliminary edition of the test. The various subtests of this battery are among the dependent variables for the longitudinal study. The standardization of the test occurred when the final version of the test battery had been developed, during the second year of the longitudinal study. To assess the magnitude of any possible practice effect arising from having tested the standardization sample a year earlier with the preliminary version of the battery, additional children who had not been exposed to any form of the test battery were tested using the final edition. Forty children at each of the four grade groups were included. This testing was performed concurrently with testing of the standardization sample. Statistical analyses failed to detect any systematic performance differences between the standardization sample and the children in the retest control sample.

TABLE 10

TOTAL NUMBER OF CHILDREN, MEAN AGE, AND AGE RANGE AT
EACH GRADE GROUP IN THE STANDARDIZATION SAMPLE

Grade Group	Number		Mean Age (in years and months)	Age Range (in years and months)
1	Total	82	6 - 10	6 - 3 to 7 - 4
	Boys	40	6 - 10	6 - 3 to 7 - 4
	Girls	42	6 - 10	6 - 4 to 7 - 4
4	Total	92	9 - 10	9 - 3 to 10 - 8
	Boys	46	9 - 10	9 - 3 to 10 - 7
	Girls	46	9 - 10	9 - 3 to 10 - 8
7	Total	91	12 - 10	12 - 2 to 13 - 8
	Boys	44	12 - 10	12 - 3 to 13 - 8
	Girls	47	12 - 9	12 - 2 to 13 - 5
10	Total	86	15 - 9	15 - 2 to 16 - 7
	Boys	43	15 - 9	15 - 3 to 16 - 7
	Girls	43	15 - 8	15 - 2 to 16 - 5

ADMINISTRATION OF THE TEST TO THE STANDARDIZATION SAMPLE

The battery was administered to the standardization sample according to the instructions specified in the Development of Conceptual Learning and Development Assessment Series I: Equilateral Triangle (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973). Tests were administered by trained personnel from the Wisconsin Research and Development Center for Cognitive Learning. For grades 4, 7, and 10 the battery was administered to classroom groups of 20 to 30 children while for the first grade it was administered to smaller groups of five to seven children. The entire battery was read to children regardless of grade level. Children marked their answers directly on the test pages; a separate answer sheet was not used.

MEANS AND STANDARD DEVIATIONS FROM THE STANDARDIZATION SAMPLE

Table 11 gives summary data for the raw scores resulting from the standardization testing. Means and standard deviations are given for each grade group on each subtest administered as well as on a combined formal level score, a total levels score, and a total uses score. Appendix A contains the same summary data for each sex for each grade group.

As mentioned in Chapter 1, it is not necessary or desirable to administer all items or subtests to each grade group. Since it is assumed, based on information collected using the preliminary version of the battery, that children in the higher grade groups would respond correctly to all concrete level and identity level items, those sub-

TABLE 11

MEANS AND STANDARD DEVIATIONS OF RAW SCORES ON EACH SUBTEST
AND ON A COMBINED FORMAL SCORE, TOTAL LEVELS SCORE, AND TOTAL USES
SCORE, BY GRADE GROUP FOR THE STANDARDIZATION SAMPLE

Subtest	Grade Group			
	1 (n=82)	4 (n=92)	7 (n=91)	10 (n=86)
Concrete (8 items)				
Mean	7.74	7.84	NA ^a	NA ^a
SD	.60	.52		
Identity (8 items)				
Mean	7.76	7.84	NA ^a	NA ^a
SD	.56	.40		
Classificatory (3 items)				
Mean	2.48	2.74	2.82	2.84
SD	.86	.69	.53	.59
Evaluating & Defining (6 items)				
Mean	1.09	2.65	3.22	3.97
SD	1.02	1.35	1.43	1.51
Discriminating Attributes (5 items)				
Mean	2.98	4.23	4.58	4.76
SD	1.32	1.00	.94	.77
Naming (7 items)				
Mean	2.55	3.71	5.18	5.91
SD	1.45	1.61	1.60	1.44
Combined Formal (18 items)				
Mean	6.61	10.59	12.98	14.63
SD	2.54	2.89	3.06	3.18
Total Levels (37 items)				
Mean	24.59	29.00	31.80	33.47
SD	3.08	3.14	3.20	3.32
Supraordinate-Subordinate Relationships (8 items)				
Mean	NA ^b	4.34	4.47	5.94
SD		1.60	1.77	2.09

TABLE 11 (cont.)

Subtest	Grade Group			
	1 (n=82)	4 (n=92)	7 (n=91)	10 (n=86)
Principles (11 items)				
Mean	NA ^b	4.51	7.14	8.98
SD		2.15	2.56	2.54
Problem Solving (6 items)				
Mean	NA ^b	2.13	3.08	4.41
SD		1.22	1.43	1.67
Total Uses (25 items)				
Mean	NA ^b	10.98	14.68	19.33
SD		3.53	4.30	5.62

^a NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too easy for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group. All children in this grade group received full credit for this subtest in the computation of the total levels score.

^b NA (Not administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too difficult for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group.

tests were administered to grade groups 1 and 4 only.¹ On the other hand, primary-aged children respond incorrectly to most items in the three concept usage subscales: supraordinate-subordinate relations, principles, and problem solving. Therefore, those three subtests were not administered to grade group 1 of the standardization sample. All other subtests were administered to each grade group.

¹ Although summary data on the concrete level and identity level subtests are presented for the grade 4 group, examination of the data suggests that the subtests are too easy for use with grade 4 as well (see Table 1, Chapter 1).

III

STATISTICAL PROPERTIES

In reporting statistical data, three summary scores have been employed. The three subtests which are part of the formal level have been included in the combined formal score which is equal to their sum. Inasmuch as the scores on these three subtests are always used in conjunction to assess attainment at the formal level, information on their individual properties is of lesser interest. A total levels score equal to the sum of the concrete level, identity level, classificatory level, and combined formal scores and a total uses score equal to the sum of the supraordinate-subordinate relationships, principles, and problem-solving subtest scores are also presented. These two total scores provide summative indices of the two major aspects of the CLD model, namely conceptual attainment and conceptual utilization and extension.

RELIABILITY

Internal consistency for this battery was determined by the use of Hoyt's analysis of variance procedure, which is algebraically equivalent to Kuder Richardson's formula 20 and Cronbach's coefficient alpha. Internal consistency is of more interest than test-retest reliability in this battery, given that children's attainment of concepts is not expected to remain stable over time. Table 12 presents the Hoyt reliability coefficients and standard errors of measurement of the individual

TABLE 12

HOYT RELIABILITY COEFFICIENTS AND STANDARD ERRORS OF MEASUREMENT ON EACH SUBTEST AND ON A COMBINED FORMAL SCORE, TOTAL LEVELS SCORE, AND TOTAL USES SCORE, BY GRADE GROUP AND ACROSS THE FOUR GROUPS FOR THE STANDARDIZATION SAMPLE

Subtest	Grade Group				
	1 (n=82)	4 (n=92)	7 (n=91)	10 (n=86)	All Grades (n=351)
Concrete (8 items)					
Reliability	.41	NR ^a	NA ^b	NA ^b	.46
SE _M	.43				.28
Identity (8 items)					
Reliability	.32	NR ^a	NA ^b	NA ^b	.26
SE _M	.43				.28
Classificatory (3 items)					
Reliability	.64	.75	.60	.83	.71
SE _M	.42	.28	.27	.20	.30
Combined Formal (18 items)					
Reliability	.50	.60	.72	.81	.83
SE _M	1.74	1.78	1.57	1.33	1.64
Total Levels (37 items)					
Reliability	.57	.59	.71	.80	.83
SE _M	2.00	1.98	1.69	1.48	1.88
Supraordinate-Subordinate Relationships (8 items)					
Reliability	NA ^c	.41	.53	.78	.69 ^d
SE _M		1.14	1.14	.92	1.10
Principles (11 items)					
Reliability	NA ^c	.54	.72	.83	.91 ^d
SE _M		1.38	1.28	1.00	1.12
Problem-Solving (6 items)					
Reliability	NA ^c	.26	.48	.74	.79 ^d
SE _M		.96	.94	.77	.83
Total Uses (25 items)					
Reliability	NA ^c	.61	.75	.91	.93 ^d
SE _M		2.15	2.10	1.67	1.91

TABLE 12 (cont.)

^a NR (Not Reported). Upon examination of the results of the standardized testing, as indicated by the means and standard deviations reported in Table 11, this subtest was found to be too easy for use with this grade group (see Table 1, Chapter 1). Accordingly, reliability information would be meaningless and is not reported.

^b NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too easy for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group. All children in this grade group received full credit for this subtest in the computation of the total levels statistic and in the computation of the all grades concrete and identity subtest statistics.

^c NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too difficult for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group.

^d Primary aged children who did not receive this subtest were treated as earning total scores of zero in computing test statistics across grades.

subtests and of the combined formal level score, total levels score, and total uses score within each grade group and across the four grade groups.

Examination of Table 12 reveals that of the 35 Hoyt reliabilities reported over half are .70 or better. Inspection of Table 11 containing means and standard deviations indicates that many of the lower reliabilities were obtained in cases where subtest means were over 90 percent of the total possible subtest score and standard deviations were very small. Means in this range and low standard deviations indicate an attenuation of the range of obtained scores which precludes higher Hoyt reliabilities being obtained. Although these subtests do not discriminate among the majority of the children in these grade groups, they provide valuable information concerning the children who may not have attained the corresponding level of conceptual development or facility in concept utilization. Other low reliabilities were obtained in cases where the associated means and standard deviations were very low, again precluding higher Hoyt reliabilities being obtained. These subtests will nonetheless identify children who have attained higher levels of conceptual development or greater facility in concept utilization.

ITEM DIFFICULTIES (PERCENT OF CORRECT RESPONSE)

Item difficulties in the form of percent of correct response to each item by grade group and across the grade groups are included in Appendix B. Point biserial correlations of each item with the total test score across the four grade groups are also presented.

The point biserial correlations were obtained by relating each of the items in the concrete level, identity level, classificatory level, and combined formal level subtests to the total levels score

and each of the items in the supraordinate-subordinate relationships, principles, and problem solving subtests to the total uses score.

The fact that a greater percent of children answer a test item correctly in higher grade groups than in lower grade groups provides some evidence for the validity of the item. In grade groups 7 and 10 it is more likely that children have received instruction in the concept equilateral triangle than it is in grade groups 1 and 4. Thus it is expected that they would perform better than the children in the lower grade groups. The item difficulties reported in Appendix B conform to this expected pattern in almost all cases.

INTERCORRELATION OF THE TOTAL LEVELS SCORE WITH THE TOTAL USES SCORE

The intercorrelation of the total levels score with the total uses score is presented in Table 13 for each of the grade groups and across all the grade groups. The intercorrelation of the scores was not computable for grade group 1, since they did not receive any of the uses subtests. The range of correlations within each grade group is .44 to .73; the intercorrelation of the scores when all grade groups are combined is .80. These intercorrelations give support to the assumption that concept utilization is positively related to concept attainment.

PATTERNS OF CONCEPT ATTAINMENT

One important use of the Conceptual Learning and Development Assessment Series I: Equilateral Triangle is in the placement of individual children on the continuum of conceptual development with

TABLE 13

INTERCORRELATION OF THE TOTAL LEVELS SCORE AND THE
TOTAL USES SCORE, BY GRADE GROUP AND ACROSS
GRADE GROUPS FOR THE STANDARDIZATION SAMPLE

Grade Group	Correlation
1 (n = 82)	NA ^a
4 (n = 92)	.44
7 (n = 91)	.51
10 (n = 86)	.73
All Grade Groups (n = 351)	.80

^aNA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, all of the uses subtests were judged to be too difficult for use with first-grade children. Thus, when the final edition was administered these subtests were not included for this grade group.

respect to the concept equilateral triangle. For some applications it is desirable to reduce this information to the single datum of the level at which the child is performing. To facilitate this placement, a scoring scheme has been developed to indicate mastery vs. nonmastery of each of the concrete level, identity level, classificatory level, and combined formal subtests. All items are given equal weight, and full attainment of a level is indicated by a score greater than or equal to a predefined criterion score on the corresponding subtest. These criteria are presented in Table 14.

Inasmuch as the test battery charts a child's passage through qualitatively different levels of conceptual attainment as additional cognitive operations are acquired, traditional indices of test performance suitable for use with norm-referenced measures are not entirely appropriate and may not adequately reflect the performance of the battery. Accordingly, in addition to Hoyt coefficients of reliability and traditional item statistics, a criterion-referenced scoring scheme is presented, and patterns of percent mastery across grade groups and across subtests assessing successive levels of conceptual attainment are also presented and discussed.

Table 15 presents the number and proportion of children within and across the four grade groups who mastered each of the four levels of concept attainment. According to the CLD model, the percentage of children passing each of the four successive levels should decrease within each grade group. Furthermore, for each of the four levels, the percentage of children passing should increase from the lower to the higher grade groups. Inspection of Table 15 reveals that only one exception to these predictions occurred, and that was an increase

TABLE 14
NUMBER OF ITEMS AND CRITERIA DEFINING FULL ATTAINMENT
FOR EACH CONCEPT LEVEL

Subtest	Number of Items	Criterion for Full Attainment
Concrete	8	7 correct
Identity	8	7 correct
Classificatory	3	3 correct
Combined Formal		
Evaluating and Defining	6	15 items correct
Discriminating Attributes	5	or approximately 80% of combined
Naming	7	formal items

TABLE 15

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT
FULLY MASTERED EACH LEVEL OF ATTAINMENT

Grade	Concrete	Identity	Classificatory	Combined Formal
1st (n=82)				
Number	77	77	54	0
Proportion	.94	.94	.66	.00
4th (n=92)				
Number	90	91	77	5
Proportion	.98	.99	.84	.05
7th (n=91)				
Number	91	91	79	35
Proportion	1.00	1.00	.87	.38
10th (n=86)				
Number	86	86	79	56
Proportion	1.00	1.00	.92	.65
All Grades (n=351)				
Number	344	345	289	96
Proportion	.98	.98	.82	.27

of only one percent where a decrease was predicted, from concrete level to identity level for grade group 4. It will be recalled that the administration of the concrete and identity level subtests is not recommended at this grade level. Overall, the proportion of the 351 children who passed the various levels was .98, concrete level, .98, identity level, .82, classificatory level, and .27, formal level. In the light of the theoretical predictions of the CLD model, these results support the validity of mastery decisions made on the basis of the test battery.

In addition to placing individual children at one of the four levels, these mastery decisions permit the examination of validity of the test battery in the light of the hierarchical nature of the model. Inasmuch as attainment of each level requires the presence of conceptual abilities characteristic of the preceding levels, the model predicts that no child should master any one of the four levels subtests unless he also masters all preceding levels subtests. It is hypothesized that each successive level of attainment requires the use of one or more new cognitive operations. Therefore each subtest would be more difficult than the previous one. A given pattern of attainment as indicated by the four mastery decisions derived from the levels subtests may be represented by a string of four letters, each either "P" or "F," denoting mastery (Passing) or nonmastery (Failing) of the corresponding subtest. The leftmost letter in such a string represents the concrete level subtest; the second, identity level; the third, classificatory; and the rightmost, combined formal. Thus, the pattern of attainment of a child who mastered the concrete level and identity level subtests and failed to master the classificatory level and combined formal subtests

would be represented by the string "PPFF." On the basis of the hierarchical nature of the model, it is predicted that all children will attain one of the following 5 of the 16 possible patterns: FFFF, PFFF, PPFF, PPPF, and PPPP.

Table 16 shows the number and proportion of each grade group that attained the successive levels according to the five patterns and also the number and proportion of each grade group that were exceptions to the five patterns. Information regarding those who performed according to the predicted patterns is given in the top five rows; the exceptions are given in the lower rows. Of the 354 children, 341 or 97 percent performed according to the predicted patterns; only 3 percent or 10 children failed to conform to expected patterns.

The high percentage of children conforming to the predicted patterns supports the major proposition of the CLD model, that individuals attain concepts in a highly predictable pattern involving the four successive levels: concrete, identity, classificatory, and formal. The results also support the validity of the test battery as effectively charting the course of the development of the concept equilateral triangle.

TABLE 16

NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND
NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	1st (n=82)	4th (n=92)	7th (n=91)	10th (n=86)	All Grades (n=351)
FFFF	4 .05	0 .00	0 .00	0 .00	4 .01
PFFF	1 .01	1 .01	0 .00	0 .00	2 .01
PPFF	23 .28	13 .14	9 .10	4 .05	49 .14
PPPF	53 .65	71 .77	47 .52	26 .30	197 .56
PPPP	0 .00	4 .04	32 .35	53 .62	89 .25
Subtotal Conforming	81 .99	89 .97	88 .97	83 .97	341 .97
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	0 .00	0 .00	0 .00	0 .00	0 .00
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	0 .00	0 .00	0 .00	0 .00	0 .00
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	1 .01	2 .02	0 .00	0 .00	3 .01
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	0 .00	1 .01	3 .03	3 .03	7 .02
Subtotal Not Conforming	1 .01	3 .03	3 .03	3 .03	10 .03

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APPENDIX A

DESCRIPTION SCALE STATISTICS FOR THE
EQUILATERAL TRIANGLE BATTERY

TABLE A-1

MEANS AND STANDARD DEVIATIONS OF RAW SCORES ON EACH SUBTEST
AND ON A COMBINED FORMAL SCORE, TOTAL LEVELS SCORE, AND TOTAL USES
SCORE, BY GRADE GROUP, FOR BOYS IN THE STANDARDIZATION SAMPLE

Subtest	Grade Group			
	1 (n=40)	4 (n=47)	7 (n=44)	10 (n=43)
Concrete (8 items)				
Mean	7.85	7.81	NA ^a	NA ^a
SD	.36	.54		
Identity (8 items)				
Mean	7.88	7.81	NA ^a	NA ^a
SD	.40	.40		
Classificatory (3 items)				
Mean	2.55	2.68	2.80	2.95
SD	.71	.73	.55	.21
Evaluating & Defining (6 items)				
Mean	1.20	2.64	2.75	3.72
SD	1.11	1.33	1.48	1.53
Discriminating Attributes (5 items)				
Mean	3.08	4.43	4.55	4.74
SD	1.31	.77	1.04	.88
Naming (7 items)				
Mean	2.58	3.70	4.77	5.88
SD	1.43	1.53	1.52	1.65
Combined Formal (18 items)				
Mean	6.85	10.77	12.07	14.35
SD	2.39	2.44	3.10	3.51
Total Levels (37 items)				
Mean	25.13	29.11	30.86	33.30
SD	2.60	2.71	3.19	3.56
Supraordinate-Subordinate Relationships (8 items)				
Mean	NA ^b	4.51	4.36	5.86
SD		1.54	1.66	2.26

TABLE A-1 (cont.)

Subtest	Grade Group			
	1 (n=40)	4 (n=47)	7 (n=44)	10 (n=43)
Principles (11 items)				
Mean	NA ^b	4.62	6.86	8.95
SD		1.94	2.59	2.66
Problem Solving (6 items)				
Mean	NA ^b	2.02	3.23	4.65
SD		1.19	1.36	1.56
Total Uses (25 items)				
Mean	NA ^b	11.15	14.45	19.47
SD		3.18	4.06	5.83

^a NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too easy for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group. All children in this grade group received full credit for this subtest in the computation of the total levels score.

^b NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too difficult for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group.

TABLE A-2

MEANS AND STANDARD DEVIATIONS OF RAW SCORES ON EACH SUBTEST
AND ON A COMBINED FORMAL SCORE, TOTAL LEVELS SCORE, AND TOTAL USES
SCORE, BY GRADE GROUP, FOR GIRLS IN THE STANDARDIZATION SAMPLE

Subtest	Grade Group			
	1 (n=42)	4 (n=45)	7 (n=47)	10 (n=43)
Concrete (8 items)				
Mean	7.64	7.87	NA ^a	NA ^a
SD	.76	.50		
Identity (8 items)				
Mean	7.64	7.87	NA ^a	NA ^a
SD	.66	.40		
Classificatory (3 items)				
Mean	2.40	2.80	2.85	2.72
SD	.99	.66	.51	.80
Evaluating & Defining (6 items)				
Mean	.98	2.67	3.66	4.21
SD	.92	1.40	1.24	1.46
Discriminating Attributes (5 items)				
Mean	2.88	4.02	4.62	4.77
SD	1.35	1.16	.85	.65
Naming (8 items)				
Mean	2.52	3.71	5.55	5.93
SD	1.49	1.71	1.59	1.22
Combined Formal (18 items)				
Mean	6.38	10.40	13.83	14.91
SD	2.68	3.31	2.79	2.84
Total Levels (37 items)				
Mean	24.07	28.89	32.68	33.63
SD	3.42	3.54	2.99	3.11
Supraordinate-Subordinate Relationships (8 items)				
Mean	NA ^b	4.16	4.55	6.02
SD		1.64	1.89	1.93

TABLE A-2 (cont.)

Subtest	Grade Group			
	1 (n=42)	4 (n=45)	7 (n=47)	10 (n=43)
Principles (11 items)				
Mean	NA ^b	4.40	7.40	9.00
SD		2.36	2.53	2.45
Problem Solving (6 items)				
Mean	NA ^b	2.24	2.94	4.16
SD		1.26	1.50	1.76
Total Uses (25 items)				
Mean	NA ^b	10.80	14.90	19.19
SD		3.90	4.55	5.47

^a NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too easy for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group. All children in this grade group received full credit for this subtest in the computation of the total levels score.

^b NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too difficult for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group.

APPENDIX B

DESCRIPTIVE ITEM STATISTICS FOR THE
EQUILATERAL TRIANGLE BATTERY

TABLE B-1

DIFFICULTIES OF EACH ITEM IN THE TOTAL LEVELS SCORE BY GRADE GROUP,
AND DIFFICULTIES AND POINT BISERIAL CORRELATIONS FOR THE SAME ITEMS
COMBINING GRADE GROUPS FOR THE STANDARDIZATION SAMPLE

Item	1(n = 82) Difficulty	4(n = 92) Difficulty	7(n = 91) Difficulty	10(n = 86) Difficulty	Combined Grades (n = 351) Difficulty	r
Concrete Subtest						
1	1.00	NR ^a	NA ^b	NA ^b	1.00	.00
2	1.00	NR ^a	NA ^b	NA ^b	1.00	.00
3	1.00	NR ^a	NA ^b	NA ^b	1.00	.00
4	1.00	NR ^a	NA ^b	NA ^b	.99	.02
5	.98	NR ^a	NA ^b	NA ^b	.99	.12
6	.98	NR ^a	NA ^b	NA ^b	.99	.18
7	.90	NR ^a	NA ^b	NA ^b	.96	.28
8	.88	NR ^a	NA ^b	NA ^b	.96	.30
Identity Subtest						
9	1.00	NR ^a	NA ^b	NA ^b	1.00	.02
10	.99	NR ^a	NA ^b	NA ^b	.99	.09
11	1.00	NR ^a	NA ^b	NA ^b	1.00	.00
12	.98	NR ^a	NA ^b	NA ^b	.99	.17
13	1.00	NR ^a	NA ^b	NA ^b	1.00	.00
14	1.00	NR ^a	NA ^b	NA ^b	1.00	.00
15	.92	NR ^a	NA ^b	NA ^b	.92	.29
16	.88	NR ^a	NA ^b	NA ^b	.96	.25
Classificatory Subtest						
17	.90	.95	.95	.95	.94	.32
18	.81	.89	.95	.93	.89	.26
19	.77	.90	.93	.95	.89	.33
Combined Formal Subtest Evaluating & Defining						
20	.17	.53	.51	.60	.46	.44
21	.20	.54	.75	.84	.59	.61
22	.33	.63	.78	.87	.66	.59
23	.13	.42	.41	.53	.38	.37
24	.18	.23	.29	.43	.28	.35
25	.07	.29	.49	.69	.39	.33

TABLE B-1 (cont.)

Item	1(n = 82) Difficulty	4(n = 92) Difficulty	7(n = 91) Difficulty	10(n = 86) Difficulty	Combined Grades (n = 351) Difficulty	r
Discriminating Attributes						
26	.70	.91	.93	.95	.88	.45
27	.39	.84	.88	.92	.76	.53
28	.67	.92	.96	.97	.88	.44
29	.60	.86	.95	.97	.85	.51
30	.62	.70	.87	.95	.79	.47
Naming						
31	.39	.45	.75	.81	.60	.50
32	.79	.67	.77	.93	.79	.32
33	.28	.58	.86	.91	.77	.63
34	.33	.68	.84	.90	.69	.58
35	.44	.59	.77	.85	.66	.51
36	.15	.32	.48	.80	.44	.61
37	.17	.42	.71	.71	.51	.52

^a NR (Not Reported). Upon examination of the results of the standardized testing, as indicated by the means and standard deviations reported in Table 11, this subtest was found to be inappropriate for use with this grade group (see Table 1, Chapter 1). Accordingly, item statistics would be meaningless and are not reported.

^b NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too easy for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group. All children in this grade group received full credit for this subtest in the computation of the total levels statistic and in the computation of the combined grades concrete and identity subtest statistics.

TABLE B-2

DIFFICULTIES OF EACH ITEM IN THE TOTAL USES SCORE BY GRADE GROUP,
AND DIFFICULTIES AND POINT BISERIAL CORRELATIONS FOR THE SAME ITEMS
COMBINING GRADE GROUPS FOR THE STANDARDIZATION SAMPLE

Item	1(n = 82) Difficulty	4(n = 92) Difficulty	7(n = 91) Difficulty	10(n = 86) Difficulty	Combined Grades (n = 351) Difficulty	r
Supraordinate-Subordinate Relationships						
1	NA ^a	.78	.73	.90	.76	.49
2	NA ^a	.30	.48	.86	.51	.32
3	NA ^a	.66	.78	.73	.63	.40
4	NA ^a	.62	.71	.85	.66	.51
5	NA ^a	.73	.73	.84	.70	.41
6	NA ^a	.13	.23	.47	.21	.42
7	NA ^a	.70	.45	.65	.46	.55
8	NA ^a	.41	.35	.61	.36	.48
Principles						
9	NA ^a	.59	.79	.91	.58	.72
10	NA ^a	.60	.82	.91	.59	.74
11	NA ^a	.49	.68	.90	.52	.72
12	NA ^a	.65	.84	.93	.62	.75
13	NA ^a	.18	.45	.71	.34	.61
14	NA ^a	.04	.40	.71	.29	.70
15	NA ^a	.40	.74	.84	.50	.70
16	NA ^a	.37	.68	.77	.46	.65
17	NA ^a	.35	.56	.84	.44	.69
18	NA ^a	.55	.79	.81	.55	.69
19	NA ^a	.28	.40	.66	.35	.58
Problem Solving						
20	NA ^a	.63	.88	.92	.62	.72
21	NA ^a	.29	.69	.86	.47	.75
22	NA ^a	.46	.45	.70	.41	.61
23	NA ^a	.21	.45	.71	.34	.66
24	NA ^a	.48	.41	.74	.41	.63
25	NA ^a	.07	.20	.48	.20	.47

^a NA (Not Administered). On the basis of test results obtained with the preliminary edition of the battery, this subtest was judged to be too difficult for use with this grade group. Thus, when the final edition was administered this subtest was not included for this grade group. In computing combined grades statistics these children were treated as earning scores of zero.

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Wayne Otto
Center Co-directors

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Studies in Reading, Language
and Communication

Marvin J. Fruth
Area Chairperson
Studies of Implementation of
Individualized Schooling

Herbert J. Klausmeier
Area Chairperson
Studies of Instructional Programming
for the Individual Student

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Professor
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Associate Professor
Curriculum and Instruction

W. Patrick Dickson
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Child and Family Studies

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Educational Administration

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Mathematics
Curriculum and Instruction

Frank H. Hooper
Professor
Child and Family Studies

Dale D. Johnson
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Curriculum and Instruction

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Child and Family Studies

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Curriculum and Instruction

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Educational Administration

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Curriculum and Instruction

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Professor
Curriculum and Instruction

Gary G. Wehlage
Associate Professor
Curriculum and Instruction